

Technological Improvements in Lead-Acid Batteries

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The first practical lead-acid batteries were invented well over 100 years ago. The technical knowledge for the economical manufacturing of reliable and rechargeable lead-acid batteries was in

place by the end of the nineteenth century. Since then, batteries have made vital contributions to the conversion, portability, and storage of energy. Throughout their evolution, lead-acid batteries have been adapted to meet the increasing demands of a wide range of commercial opportunities and applications. As a result, the production and sale of lead-acid batteries is strong worldwide despite environmental concerns and pressure to produce even better and more cost-effective batteries. The annualized global sales of lead-acid batteries is \$10 billion, and the percentage of the overall lead market occupied by lead-acid batteries rose from 28% in 1960 to more than 73% in 1999.

Approximately 74% of lead-acid battery activity is dedicated to the supply of car-starter batteries. Other applications, such as emergency power systems, fork-lift trucks, telecommunication systems, uninterruptible power sources, remote-access power systems (RAPS), hybrid electric vehicles (HEV), and electric vehicles (EV) are becoming more important markets. Improvements in battery design, manufacturing equipment and methods, recovery technologies, active material utilization and production, supporting structures and components, and non-active components (e.g., separators, cases, and seals), have reduced costs and increased the performance of lead-acid batteries. The major advances in lead-acid batteries have been fueled by a significant reduction in manufacturing costs, a rapid growth in sales of valve-regulated lead-acid batteries (VRLA), the introduction of improved corrosion-resistant alloys, a better understanding of battery electrochemistry and the associated mechanisms that affect battery life and performance, as well as the development of low-resistance and more durable separators. As a result, the performance of the battery has almost doubled while the weight of it has been reduced

by more than 30%.

One of the most significant technological innovations in the continuing evolution of the lead-acid battery, and reflected in rapid worldwide sales growth, is the VRLA battery based on oxygen-recombination chemistry. VRLA batteries have been adopted universally in telecommunications and uninterruptible power sources for hospitals and stand-by power applications for computer and emergency systems. These batteries also can be utilized for power conditioning, remote-area power storage (i.e., solar or wind power generation) and are being specially developed for EVs and/or HEVs. Since their development and introduction in the early 1980s the recombination systems in the batteries have been undergoing an extensive program of definition and refinement. The paper by Bob Nelson presents the basic chemistry of oxygen recombination in lead-acid cells and briefly compares it with the highly developed Ni-Cd system, which also operates on the oxygen cycle. The electrolyte in the VRLA batteries is absorbed in a gel or the separator between the plates, and gases generated upon charging are recombined within the battery. This completely sealed battery type can be employed in any orientation and virtually any location.

The reliability of VRLA batteries has also significantly improved during the last five years, mainly because of research sponsored by the Advanced Lead Acid Battery Consortium. The paper by David Pregelman discusses the premature capacity loss in batteries causing battery failure prior to their expected life, research on the degradation of capacity, and developments to prevent battery failures. The research has led to an improved battery design and construction with respect to the use of compressive forces on the positive active material or the development of oxygen-resistant expanders, for example. Improved charging systems permit the battery to recharge in minutes instead of overnight. In addition, research into controlled charging has resulted in improved battery life.

Significant advances made in long-life, corrosion-resistant alloys with higher conductivity and in low-cost, oxidation resistant, thin separators have

already resulted in more durable and reliable batteries both for automotive and industrial applications. In their paper, Siegmund and Pregelman describe recent developments in grid alloys for automobile batteries. Notable among those developments are the replacement of lead-antimony alloys with lead-calcium-based alloys for improved cranking performance, reduced water loss creating maintenance-free batteries, improved recovery from deep discharge, reduced corrosion, and increasingly automated production.

New market opportunities for lead-acid battery applications have appeared in the last few years, mainly in the information-telecom market. The annual growth rate of that market is estimated 15%–20%. In addition, automobile manufacturers are moving rapidly toward a high-voltage system of energy storage and are seriously considering dual battery systems: one with a high energy rating and one with a high power rating. Because emission-free vehicles will grow in popularity, combined sales of EVs and HEVs will rise in the coming years. The prospects of increased lead-acid battery applications are challenged, however, by stringent technological specifications and competing battery chemistries, such as the nickel-metal hydride or lithium.

Major issues facing the industry include further improving the specific energy in order to meet the higher capacity requirements of new car electric systems without excessive weight penalty, improving the reliability and durability of VRLA batteries to better meet the cycling and life demands of EV and RAPS systems, continuing to reduce manufacturing costs of normal and advanced battery designs, and complying with environmental legislative regulations. One successful approach is the development of extremely corrosion-resistant and strong grid material permitting significantly new battery designs, such as thin-metal film batteries.

The market conditions and anticipated growth rate hold enormous potential for the future of the lead-acid battery industry.

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